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Chapter 1: Problem oriented analysis and systems thinking

1.1. Systems thinking is analytical thinking. Systems thinking must be holistic, it considers how all important parts work together, and it ignores details that do not matter. Systems thinking is a disciplined approach for examining problems more completely and accurately before acting. It allows us to ask better questions before jumping to conclusions.

1.2. P- over the last year the inventory of finished goods has declined steadily and as result at the end of the year it was nearly empty. This is important because at some point time when demand will exceed supply, the company will make less money than it could.

Hypothesis- in the term of model structure we have stock- finished goods ; Inflow - production; Outflow- sales; In this situation Outflow exceeds Inflow and Stock becomes smaller and smaller (finished goods has declined steadily).

Analysis -is the hypothesis (model) consistent with laws of sales and marketing and does it explain observed decreasing of finished goods.

Policy - use the model to see effect of increasing production (Inflow) .(We must be careful in increasing production because excess production can cause another problem).

Implementation- for implementation the policy we must provide enough labor , capital , equipment and improve capacity of production.

Chapter 2: Problem behavior over time

2.1 The observed problem behaviors we call a reference mode. We must define time horizon for the analysis (from start to stop time) ,and also we have to think about a boundary for what should be included in your model, because purpose of reference modes to focus the analysis on one problem only.

Chapter 3: Instantaneous cause and effect relationships

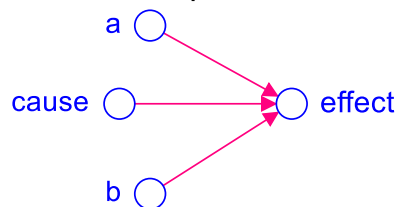
3.1. Instantaneous cause and effect relationship can be linear and nonlinear.

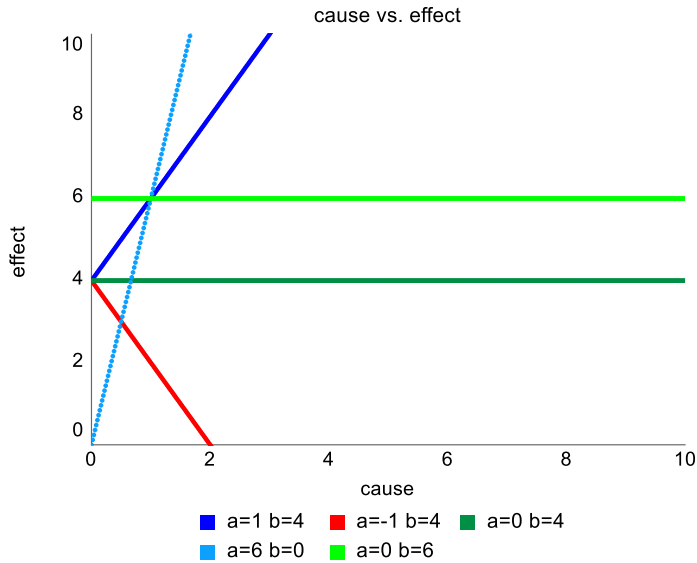
The mathematical definition of a linear relationship is the following:

$\text{Effect} = b + a \cdot \text{Cause}$

The linear cause and effect relationship can be portrayed as a straight line in a diagram with the cause on the horizontal axis and the effect on the vertical axis.

On the graph we can see couple example of linear relationship with different parameters a and b.





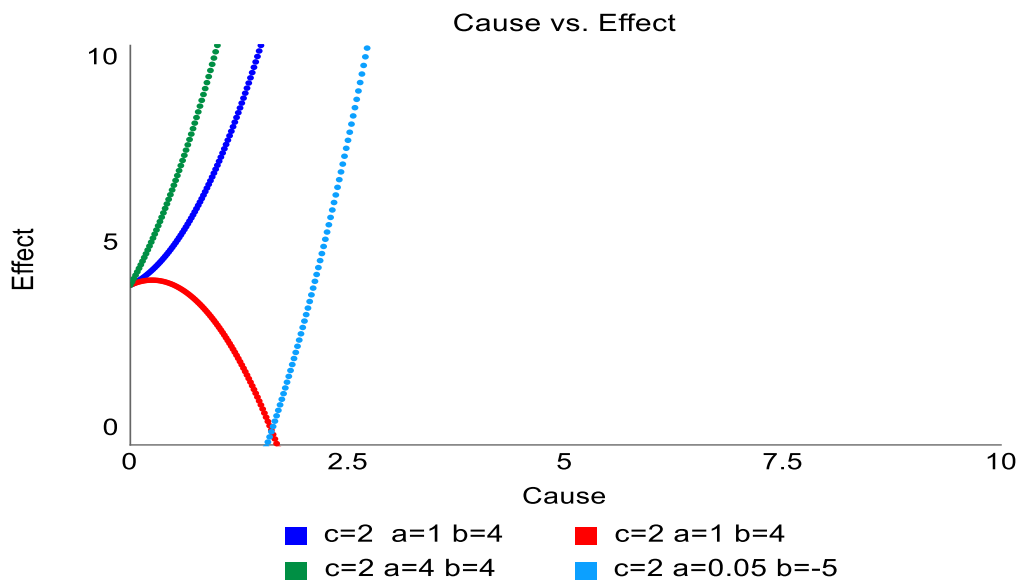
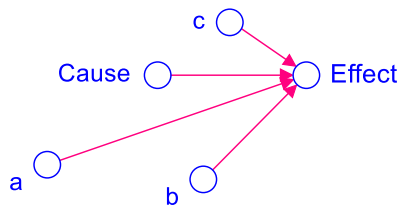
Nonlinear relationship it is all relationships that cannot be portrayed by a straight line and the above formula. The general mathematical notation for a nonlinear relationship is

$\text{Effect} = f(\text{cause})$

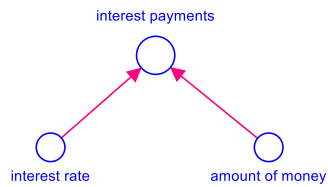
where function f is some kind of nonlinear function.

For example we have parabola with different parameters a and b and c .

$\text{Effect} = b + a \cdot \text{Cause} + c \cdot \text{Cause} \cdot \text{Cause};$



3.2 - Effect of interest rate on interest payments

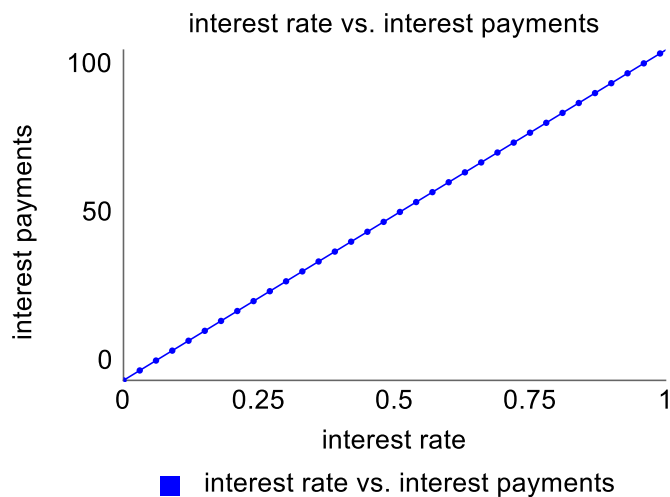


In this cases we have instantaneous relationships (linear).

$\text{interest payments (Euros per year)} = \text{interest_rate} * \text{amount_of_money}$

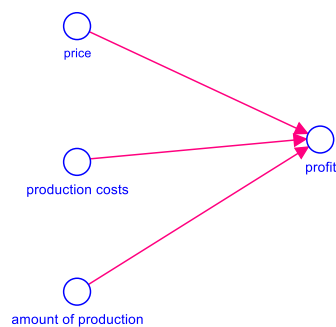
interest_rate(percentage per year , but we can conver 20% in 0,2 so it the same as

Unitless/year); amount_of_money (Euros)



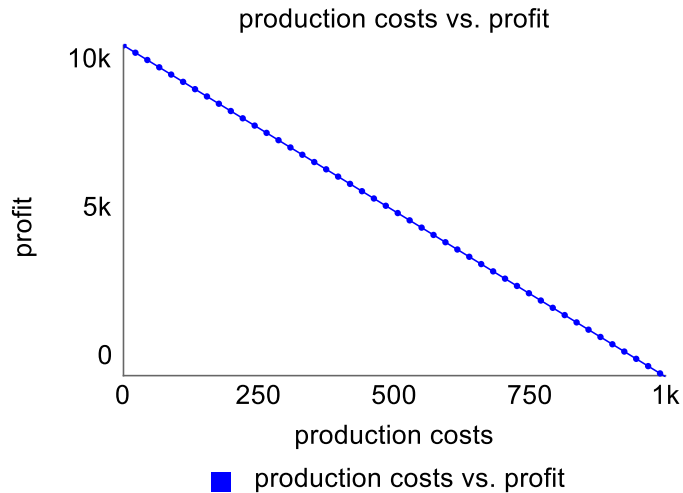
- Effect of production costs on profits

In this cases we have instantaneous relationships (linear).



$\text{profit} = (\text{price} - \text{production costs}) * \text{amount of production}$

price(Euros) ; production costs (Euros); amount of production(unitless)



- Effect of production on size of inventory

In this cases we have accumulating relationships.

Production (Inflow)(unit per time) and inventory(unit) (Stock) have not instantaneous relationship, they have an accumulation relationship.

- Effect of amount of water in a funnel on the outflow from the funnel .

In this cases we have accumulating relationships.

Amount of water in a funnel(liter) (Stock) and the outflow from the funnel (liter per time) (Outflow) have an accumulation relationship.

- Effect of births on population size

In this cases we have accumulating relationships.

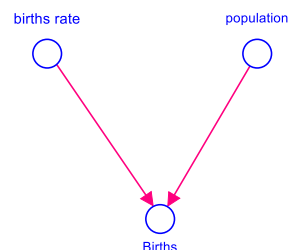
Birth (inflow)(amount people per time) and population size(amount people) (Stock) have an relationship.

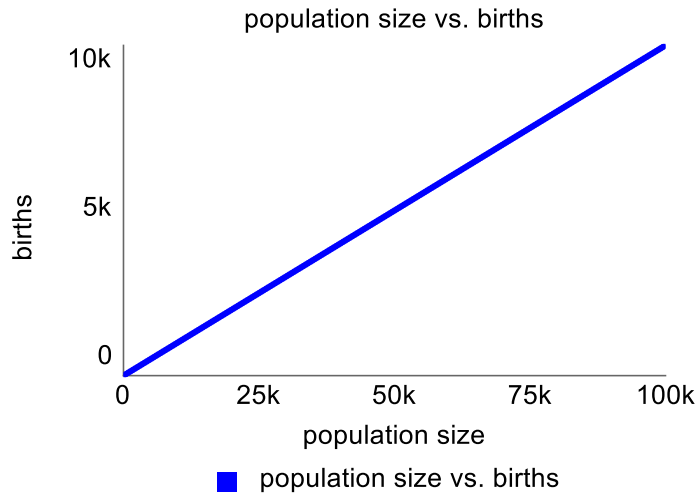
- Effect of population size on births

In this cases we have instantaneous relationships (linear).

$\text{Births} = \text{population} * \text{birth rate}$

Births(people per year); population (people); birth rate (percentage per year , but we can convert 20% in 0,2 so it the same as Unitless per year);





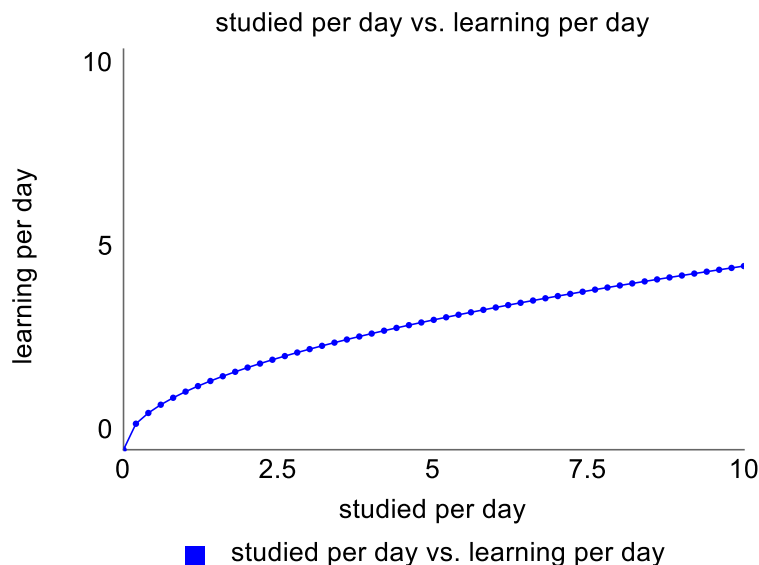
- Effect of hours studied per day on learning per day.

In this cases we have instantaneous relationships (nonlinear).

Exactly correct equation we can not define but we can draw on the graph approximately relation between hours studied per day on learning per day.

In the beginning of study, to get the result, we need to spend a certain amount of time, but over time we need to spend more and more time to learn the same amount of material as before.

Labor productivity decreases over time, and some effort produces less and less result:

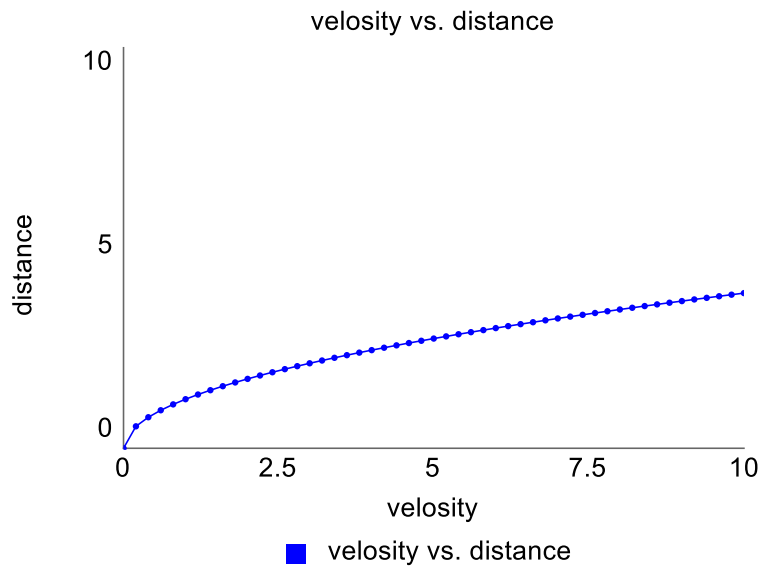


- Effect of velocity on distance travelled

We have accumulation relationship , write the equation is difficult because not simple consider the factors of fatigue (in fact it is a movement with acceleration and deceleration), we can draw

distance (meters, kilometers, miles); velocity (kilometer per hour; miles per hour); time.

And we can draw approximately on a Graph relationship:



- Effect of force on acceleration

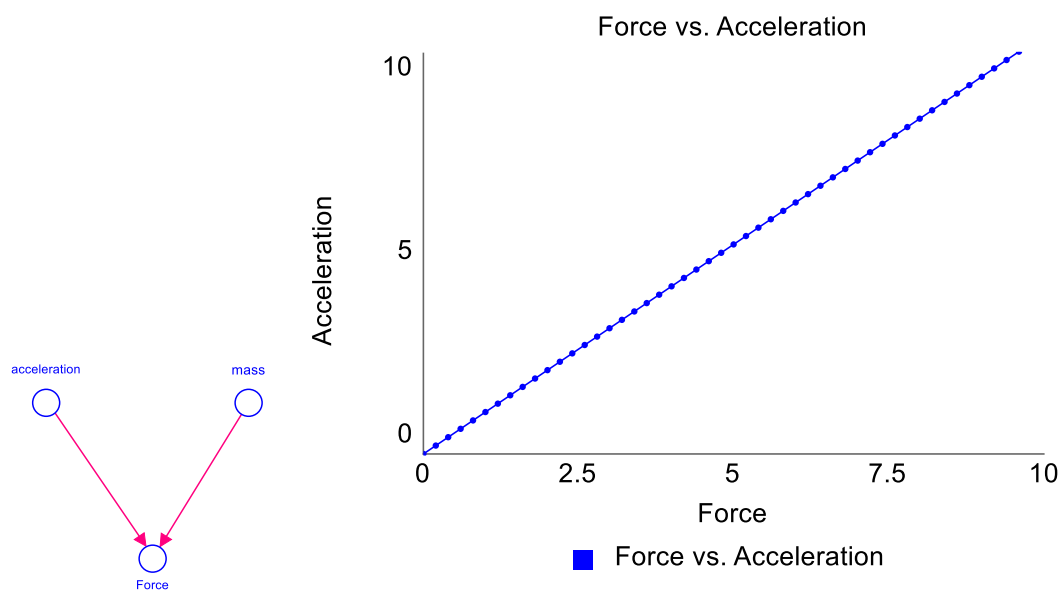
In this cases we have instantaneous relationships (linear).

Force (cause) and acceleration have instantaneous linear relationships.

$F=ma$ (second law of Newton)

Force(H); mass(kilogram) ; acceleration (meter/second²)

1H= (kilogram * meter)/second²



- Effect of acceleration on velocity

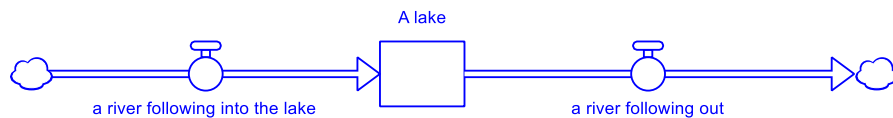
In this cases we have accumulating relationships.

We have accumulation relationship. Acceleration (meter/second²); velocity (meter per second);

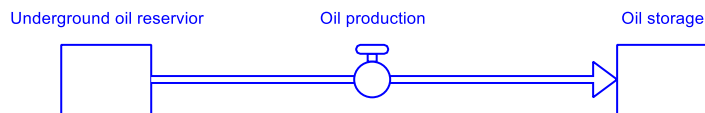
Chapter 4: Accumulating cause and effect relationships.

4.1. a)

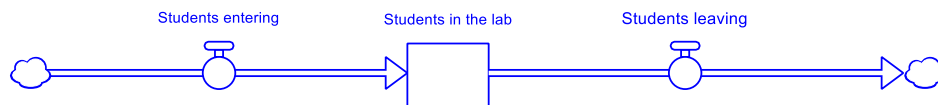
a) a lake, a river flowing into the lake and a river flowing out



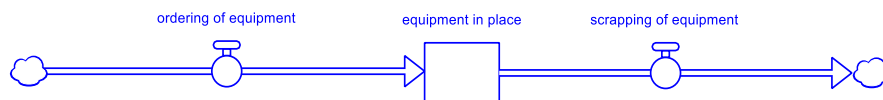
b) oil production, underground oil reservoir, oil storage



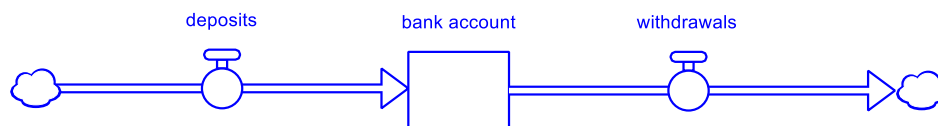
c) students in the lab, students entering, students leaving



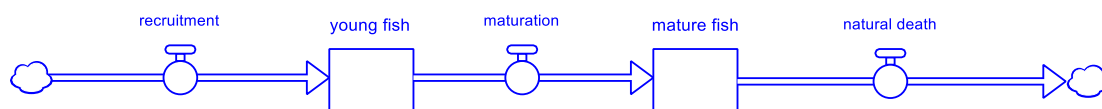
d) ordering of equipment, scrapping of equipment, equipment in place



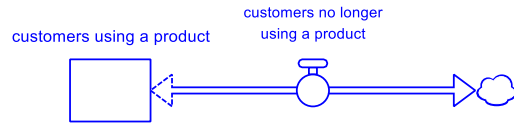
e) withdrawals, bank account, deposits



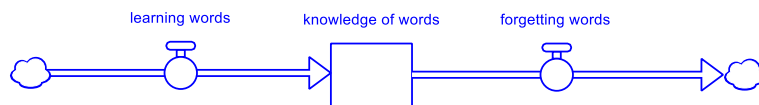
f) mature fish, maturation, natural death, recruitment, young fish



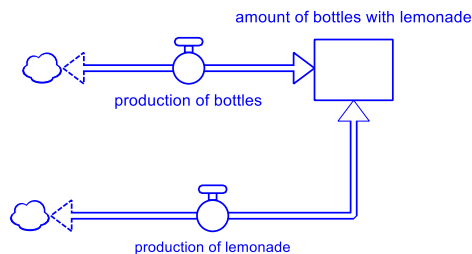
g) customers using a product and customers no longer using a product



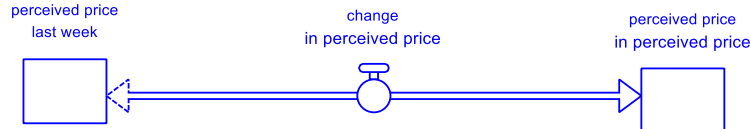
h) knowledge of words, learning words, forgetting words



i) production of bottles, production of lemonade, amount of bottles with lemonade



j) perceived price, perceived price last week, change in perceived price



4.1.b)

a) a lake : liters, gallons, cubic meters;

a river flowing into the lake/ a river flowing out: liters per hour, liters per minute, gallons per day, cubic meters per minute;

b) oil production / underground oil reservoir: US Oil Barrel (42 gallons);

oil storage : barrel per hour;

c) students in the lab : people , students;

students entering / students leaving : people per hour; people per minute;

d) ordering of equipment / scrapping of equipment: unit per day , equipment;

equipment in place: Unit , equipment;

e) withdrawals / deposits : US Dollars Per Day,

bank account: US Dollars , Euros;

f) mature fish / young fish : unit, fish, Kilograms;

maturation / natural death / recruitment : : unit per day, fish per month, Kilograms per day;

g) customers using a product (people)

customers no longer using a product (people per day)

h) knowledge of words: unit , words ;

learning words / forgetting words: unit per day , words per minute;

i) production of bottles/ production of lemonade : bottles per hour, box per day;

amount of bottles with lemonade: unit, bottles, box;

j) perceived price (Euro)

perceived price last week (Euro)

change in perceived price (Euro per day)

4.2. a) Explain why it does not matter for the analysis whether you for instance measure all flows in “per day” or “per month”. What should determine what time unit to use in a model?

For the analysis does not matter whether you measure all flows in “per day” or “per month (it does not matter for calculation and simulation), for analysis important that all of In and Outflow for particular stock have the same unit which will not contradict each other. For defining unit per month or per day or per second we should know how quickly our data is changing , because for example if we have another result calculation every second but unit will be per day we will lose many information with is important for our problem and solution.

b) For integration (simulation) in Stella Architect we use method Euler. In this method, the computed values for flows provide the estimate for the change stocks over the interval DT. In the simple model, equation look like this:

Estimate change in stocks over the interval DT.

$$\Delta \text{Stock} = dt * \text{Netflow}$$

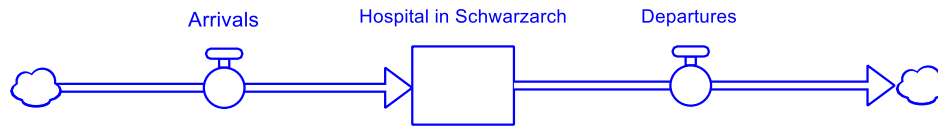
Calculate new values for Stocks based on this estimate.

$$\text{Stock}_t = \text{Stock}_{t-dt} + \Delta \text{stock}$$

Where $\Delta \text{stock} = \text{Inflow} - \text{Outflow}$

We have to measure all in- and outflows to all stocks in a model with the same time unit because according to the given method we have to subtract inflow outflows, which will be impossible if they will be in different units of measurement because the result of such subtraction will have no practical meaning.

4.3.



a) What day did most patients arrive?

The most patients arrived in 07.01.2001.

b) What day did fewest patients arrive?

The fewest patients arrived in 03.01.2001.

c) What day did most patients depart?

The most patients departed in 13.01.2001.

d) What day did fewest patients depart?

The fewest patients departed in period from 31.12.2000 to 01.01.2001 and in 06.01.2001.

e) What day were there most patients in the hospital?

The most patients in the hospital is in 08.01.2001. Because until 08.01.2001 Inflow was bigger than Outflow and $\text{Net Flow} > 0$ ($\text{Net Flow} = \text{Inflow} - \text{Outflow}$). When $\text{Net Flow} > 0$ then Stock increase.

That is, until the 8.01.2001, there was a constant increase Stock, and the greatest value will be at the last point of accumulation. Then stock will be decrease because Outflow will be bigger than Inflow ($\text{Net Flow} < 0$).

In the graph of stock behavior we can see behavior of stock, and be sure that till 08.01.2001 stock increased and accumulated.

(That graph we can build analyzing behavior Inflow and Outflow simultaneously).

f) What day were there fewest patients in the hospital considering the entire period

from the morning of 31.12.2000 to the afternoon of 13.01.2001?

(13.01.2001)